Army Research Laboratory

Blast Pendulum Testing of Milliken Tegris Panels

by Donald J. Grosch, Erick J. Sagebiel, and Hal Eleazer

ARL-CR-0600 **January 2008**

prepared by

Southwest Research Institute
San Antonio, Texas

and

Milliken & Company
Spartanburg, South Carolina

under contract

W911NF-07-2-0074

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

DESTRUCTION NOTICE—Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5069

ARL-CR-0600 **January 2008**

Blast Pendulum Testing of Milliken Tegris Panels

Donald J. Grosch and Erick J. Sagebiel
Southwest Research Institute

Hal Eleazer
Milliken & Company

prepared by

Southwest Research Institute
San Antonio, Texas

and

Milliken & Company
Spartanburg, South Carolina

under contract

W911NF-07-2-0074

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
January 2008

2. REPORT TYPE
Final

3. DATES COVERED (From - To)
July 2007 to December 2007

4. TITLE AND SUBTITLE
Blast Pendulum Testing of Milliken Tegris Panels

5a. CONTRACT NUMBER
W911NF-07-2-0074

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Donald J. Grosch and Erick J. Sagebiel (SRI); Hal Eleazer (M&C)

5d. PROJECT NUMBER
W262387171

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Southwest Research Institute, San Antonio, Texas
Milliken & Company, Spartanburg, South Carolina

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-CR-0600

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
Weapons and Materials Research Directorate
Aberdeen Proving Ground, MD 21005-5069

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
The contracting officer's representative (COR) is David Spagnuolo, U.S. Army Research Laboratory, ATTN: AMSRD-ARL-WM-MD, Aberdeen Proving Ground, MD 21005-5069, telephone number (410) 306-0770.

14. ABSTRACT
Milliken contracted Southwest Research Institute[1] (SwRI[1]) to conduct blast pendulum tests on various panels. The blast pendulum allows one to investigate a material's capability of mitigating sample deformation and bulk structural loading that result from "close-in[2]" blast loading. The methodology is based upon placing a sample in a semi-rigid frame. The frame is supported by large supports that are free to rotate about a fixed position. Based upon the angular motion, the momentum transferred into the sample can be determined. The pendulum is most useful for looking at plate coatings which hopefully can reduce the plate deformation and the overall momentum transferred into a structure. SwRI conducted a total of four tests on September 5, 2007, using the blast pendulum at its remote site near Yancey, Texas. A representative from Milliken witnessed each test.

None of the tests resulted in perforation of the target assembly, and their swing angles and deflections were considerably less than those of a baseline 3/8-inch mild steel target performed the next day (47.2-degree maximum swing with 4.53-inch maximum plate deflection) versus the best Milliken combination that showed a 41.8-degree maximum swing with 2.64-inch maximum plate deflection.

[1]Southwest Research Institute and SwRI are registered trademarks of Southwest Research Institute.
[2]The term "close-in" means within 10 to 20 meters.

15. SUBJECT TERMS
blast test data; panel deflection; tegris

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			David Spagnuolo
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR	20	19b. TELEPHONE NUMBER (*Include area code*) 410-306-0770

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

List of Tables

1. Overview

Milliken & Company contracted Southwest Research Institute (SwRI) to conduct blast pendulum tests on various panels. The blast pendulum allows one to investigate a material's capability of mitigating sample deformation and bulk structural loading that result from "close-in[1]" blast loading. The methodology is based upon placing a sample in a semi-rigid frame which is supported by large supports that are free to rotate about a fixed position. Based upon the angular motion, the momentum transferred into the sample can be determined. The pendulum is most useful for looking at plate coatings which hopefully can reduce the plate deformation and the overall momentum transferred into a structure. SwRI conducted a total of four tests on 5 September 2007, using the blast pendulum at its remote site near Yancey, Texas. A representative from Milliken witnessed each test.

2. Test Fixture

The test fixture is a large pendulum (see figures 1 and 2) onto which panels are clamped for testing. The pendulum accepts 30- by 30-inch panels, which are clamped between front and rear frame plates, each of which is fabricated from 2-inch-thick steel. Sixteen 1-inch bolts are used to clamp the two frame plates together and secure the test panel (the bolts are on the outside of the panel so no through-holes are required). The front frame has a 26-inch-square opening through which the panel is explosively loaded, while the rear frame has a 24-inch-diameter round hole through which the panel can deform or rupture. When the charge is detonated, the test panel is loaded and then deflects and transfers the load into the rest of the pendulum. The overall motion of the pendulum is recorded with high-speed video to capture the maximum swing angle. The panel deflection/rupture and the resulting swing angle can be compared to other materials loaded during similar conditions for a direct performance comparison.

[1] Close-in means within 10 to 20 meters.

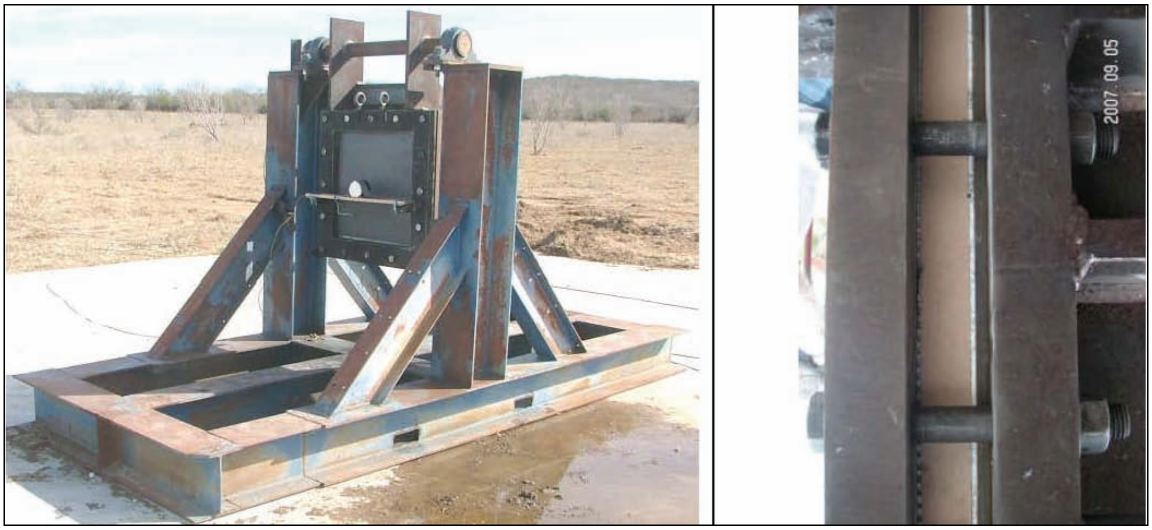


Figure 1. Blast pendulum fixture and edge view showing panel clamping.

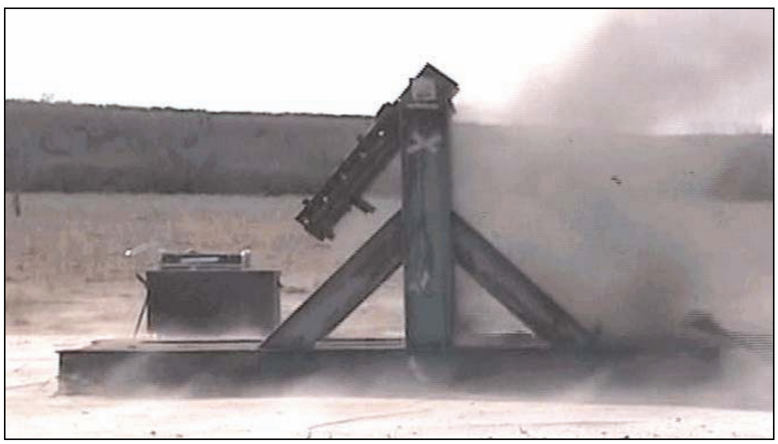


Figure 2. Picture of blast pendulum swinging after shot.

3. Explosive Charge

These tests were conducted with a bare Composition C-4 charge with a weight of 2.09 pounds and a cylindrical shape with a length-to-diameter (l/d) ratio of 0.72. This resulted in a 4-inch-diameter charge with a height of 2.88 inches. The charge was positioned "end on" to the sample, and it was center detonated on the far end of the charge (see figure 3). The stand-off distance (from the closest edge of the charge to the near face of the test panel) varied and is listed in table 1.

Figure 3. Photo of charge on fixture.

Table 1. Test results

Test	Target Description	Maximum Swing (degrees)	Maximum Plate Deflection (inches)	Comments
1	AM General Target 2.09 lb C4 charge 3-15/16-in. standoff 0.157-in. 46177 steel 0.25-in. 6061-T6 aluminum 0.25-in. 6061-T6 aluminum 1.0-in. Tegris[a] panel with aluminum skins	43.7	3.16	Steel plate has a 6-in.-dia. dent area, no cracks; 0.25-in. aluminum plate 1 has a 7-in.-dia. dent and a 7-in. crack; 0.25-in. aluminum plate 2 has a 7-in.-dia. dent and a 10-in. x 7-in. crack area; the Tegris panel has a 9-in. x 5-in. crack area on the impact side and no cracks on the back side.
2	Milliken/C-foam target 2.09-lb C4 charge 3.5-in. standoff 0.157-in. steel 1.0-in. Tegris panel with aluminum skins 1.50-in. C-foam 1.0-in. Tegris panel with aluminum skins	46.2	3.29	Steel plate has an 8-in.-dia. dent and no cracks; the 1 Tegris panel has an 8-in.-dia. dent and a 3.5-in. x 0.5-in. through crack; the C-Foam panel has a 20-in.-dia. dent area and a 2-in.-dia. hole; the 2 Tegris panel has no cracks on either surface.
3	Milliken low temp 2.09-lb C4 charge 3-7/8-in. standoff 0.157-in. steel 0.37-in. Tegris with aluminum skins 1.25-in. low temp Tegris 0.375-in. mild steel	41.8	2.64	Steel plate has a 6-in.-dia. dent and a 3-in. x 1.5-in. hole; the 0.37-in. Tegris panel has a 6-in.-dia. dent and a 3-in. x 1.5-in. hole; the low temp Tegris panel has a 6.5-in.-dia. dent and a 3-in. hole; the 3/8-in. mild steel has no cracks.
4	Milliken special panel 2.09-lb C4 charge 3-7/8-in. Standoff 0.157-in. steel 0.37-in. Tegris with aluminum skins 1.20-in. special Tegris 0.375-in. mild steel	42.0	2.50	Steel plate has a 6.5-in.-dia. dent with no cracks; the 0.37-in. Tegris panel has a 6-in.-dia. dent and a 1.5-in. x 1-in. hole; the special Tegris panel has a 6-in.-dia. dent and a 3.5-in. x 1.5-in. hole; the 3/8-in. mild steel has no cracks.

[a]Tegris is a revolutionary 100% PP thermoplastic composite with excellent impact resistance and stiffness as well as a lightweight composition. Tegris is based on a patent-pending technology which creates a highly engineered polypropylene tape yarn with a highly drawn core for strength properties within a lower melt polymer matrix for composite processing.

4. Instrumentation

A Phantom[2] V7 high-speed video camera was positioned normal to the back surface of the pendulum uprights to observe the pendulum swing. A regular-speed video camera was positioned in a similar manner as a backup. The measured swing angles are provided in table 1.

5. Test Results

A summary of the tests is shown in table 1. The maximum swing angle was measured from the high-speed video to within ±0.5 inch. The maximum plate deflection was measured by an SwRI quality assurance (QA) inspector using a coordinate measuring machine. The QA inspector scanned the center of the plate in both directions. The data from these scans are shown in figures 4 through 7. The maximum deflection values are provided in table 1. Photographs of each test are provided in appendix A.

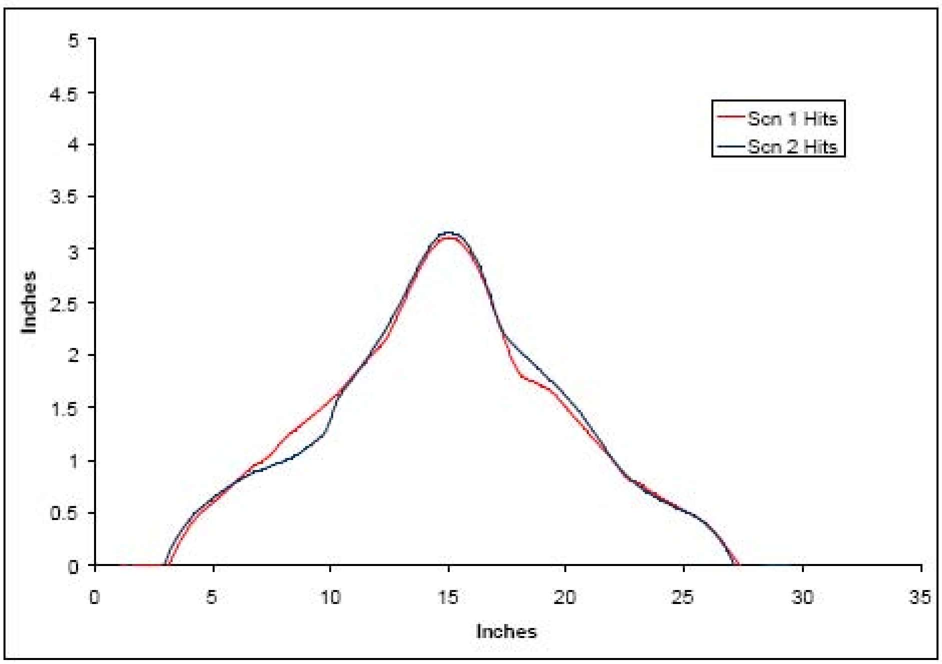


Figure 4. Plate deflection data for test 1.

[2]Phantom is a registered trademark of ViSiON Research, Inc.

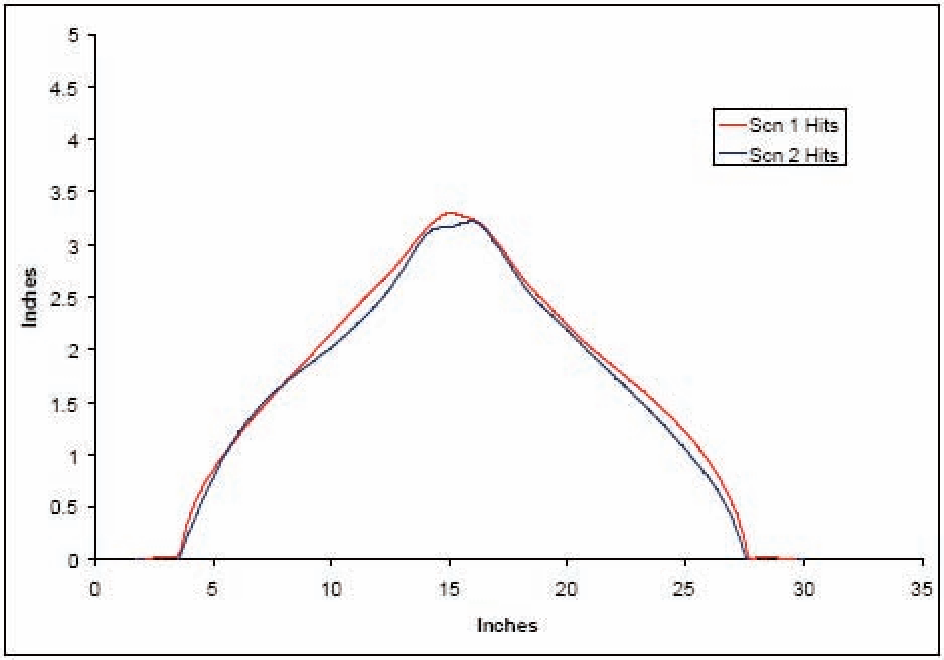


Figure 5. Plate deflection data for test 2.

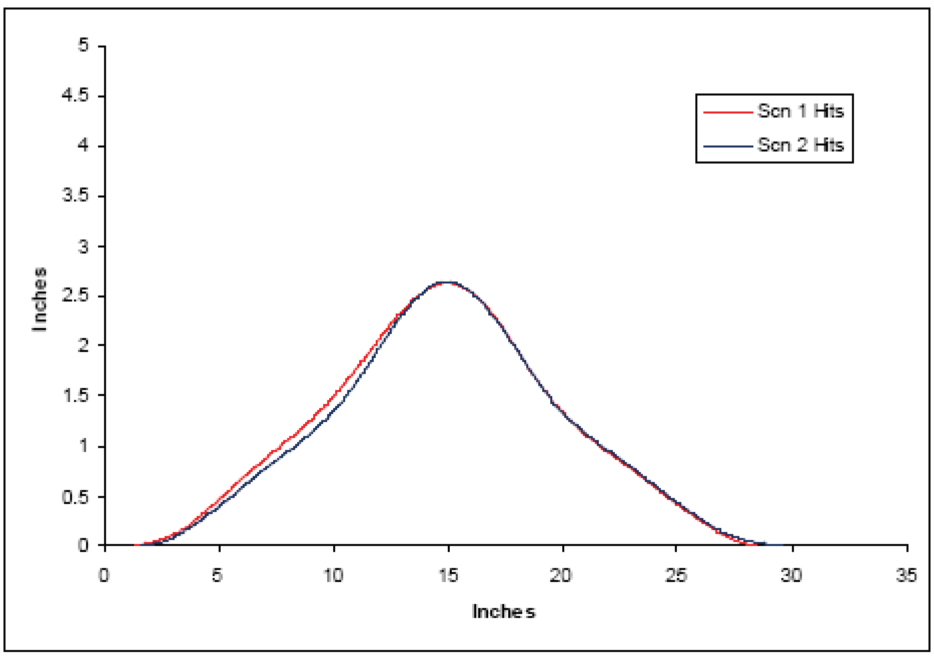


Figure 6. Plate deflection data for test 3.

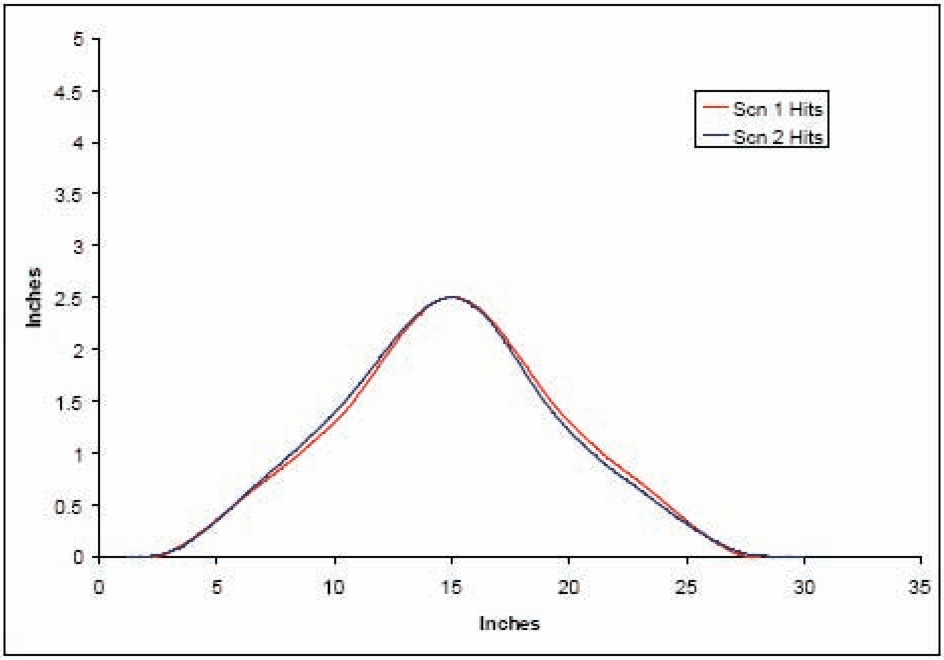


Figure 7. Plate deflection data for test 4.

6. Summary

Four pendulum blast tests were performed on panels provided by Milliken. None of the tests resulted in a perforation of the target assembly, and their swing angles and deflections were considerably less than those of a baseline 3/8-inch mild steel target performed the next day (47.2-degree maximum swing with 4.53-inch maximum plate deflection).

Appendix A. Test Photographs

Test 1 Pre-Test

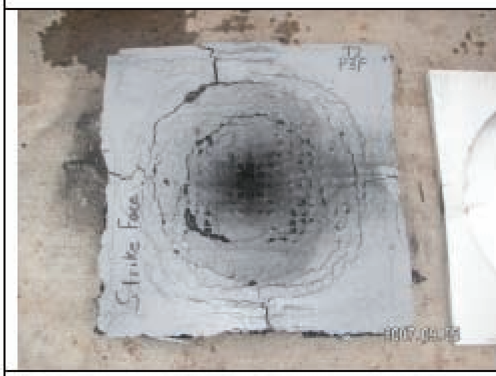
Test 1 Post-Test

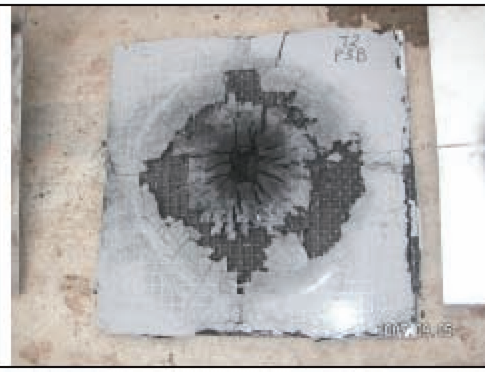
Test 1 Post-Test

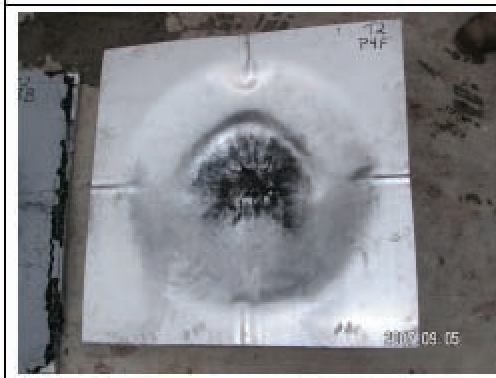
Test 2 Pre-Test	
	

Test 2 Post-Test	
	
	

Test 2 Post-Test



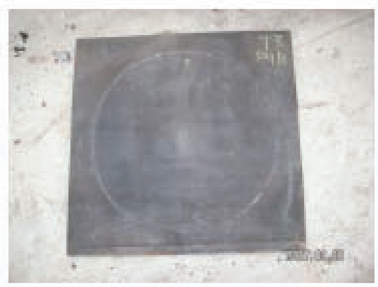




Test 3 Pre-Test

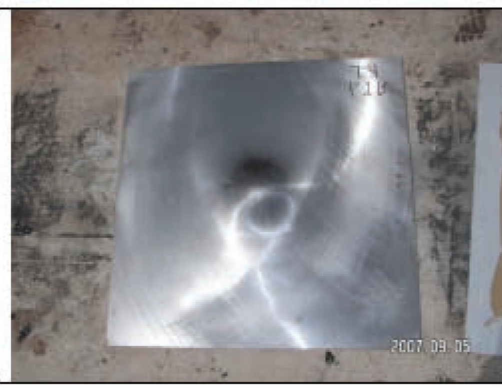
Test 3 Post-Test

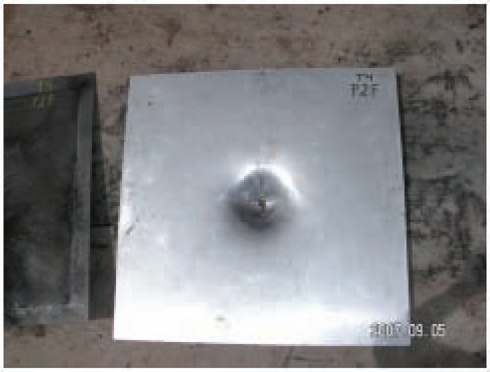
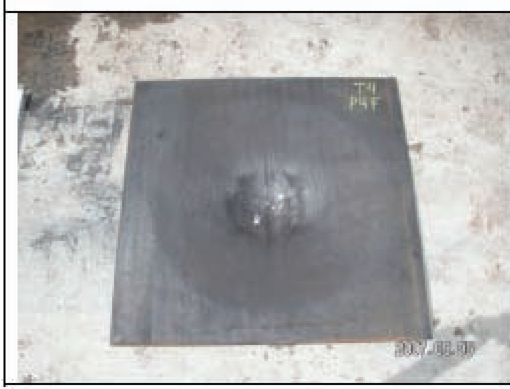
Test 3 Post-Test



Test 4 Pre-Test

Test 4 Post-Test



Test 4 Post-Test	
	
	
	

NO. OF COPIES	ORGANIZATION
1 (PDF ONLY)	DEFENSE TECHNICAL INFORMATION CTR DTIC OCA 8725 JOHN J KINGMAN RD STE 0944 FORT BELVOIR VA 22060-6218
1	US ARMY RSRCH DEV & ENGRG CMD SYSTEMS OF SYSTEMS INTEGRATION AMSRD SS T 6000 6TH ST STE 100 FORT BELVOIR VA 22060-5608
1	DIRECTOR US ARMY RESEARCH LAB IMNE ALC IMS 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL CI OK TL 2800 POWDER MILL RD ADELPHI MD 20783-1197
2	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL CS OK T 2800 POWDER MILL RD ADELPHI MD 20783-1197
2	SOUTWEST RESEARCH INST ATTN D GROSCH E SAGEBIEL 6220 CULEBRA RD SAN ANTONIO TX 78238-5166
2	MILLIKEN & COMPANY ATTN H ELEAZER 920 MILLIKEN RD SPARTANBURG SC 29303
	ABERDEEN PROVING GROUND
1	DIRECTOR US ARMY RSCH LABORATORY ATTN AMSRD ARL CI OK (TECH LIB) BLDG 4600

NO. OF COPIES	ORGANIZATION
10	DIRECTOR US ARMY RSCH LABORATORY ATTN AMSRD ARL WM MD E CHIN B CHEESEMAN J SANDS B SCOTT S WALSH D SPAGNUOLO (5 CYS) BLDG 4600